POPULATION MONITORING OF PLAIN PIGEONS IN PUERTO RICO

FRANK F. RIVERA-MILÁN,[1,2,3] CARLOS R. RUIZ,[1] JOSÉ A. CRUZ,[1] MYRNA VÁZQUEZ,[1] AND ALEXIS J. MARTÍNEZ[1]

ABSTRACT.—The Plain Pigeon (*Columba inornata*) was listed as endangered in Puerto Rico in 1970. During 1986–1992 and 1997–2001, we collected point transect survey data to estimate density, population size, and rate of change. Density and population size estimates increased between 1986–1992 and 1997–2001. With a mean density of 0.25 ± 0.06 SE individuals/ha and a mean population size in the area of the surveys of 3,746 ± 892 SE individuals during 1997–2001, we believe that the status of the Plain Pigeon is not as precarious as it was during 1986–1992, when mean density was 0.02 ± 0.003 SE individuals/ha and mean population size in the area of the surveys was 218 ± 42 SE individuals. However, Plain Pigeons are not widely distributed and the loss and fragmentation of second growth forests combined with the effects of hurricanes and other factors may cause their extinction. Because Plain Pigeons have a spatially clumped distribution, we recommend sampling at least 1,195 points during peak nesting activity (March through June) throughout the island, with at least 526 points covering areas of abundance in eastcentral Puerto Rico, to monitor population changes and evaluate the effectiveness of management actions. *Received 24 June 2002, accepted 11 December 2002.*

Plain Pigeons (*Columba inornata*) are endemic to the Greater Antilles, where they are threatened or endangered mainly by habitat loss and hunting (Wiley 1985, Pérez-Rivera 1990, Strong and Johnson 2001). Plain Pigeons were common and widespread in Puerto Rico during the 1800s (Gundlach 1878, Wetmore 1916) but became nearly extinct between the 1920s and 1930s (Danforth 1931). They reportedly were hunted between the 1940s and 1960s, and a small population was found at the municipality of Cidra in eastcentral Puerto Rico in 1963 (Leopold 1963). Plain Pigeons endured a population bottleneck between the 1920s and 1960s (Miyamoto et al. 1994) and were listed as endangered in 1970 (U.S. Fish and Wildlife Service 1982).

As with many species listed under the Endangered Species Act (Tear et al. 1995), guesses and best estimates were used for listing Plain Pigeons. Between 1973 and 1983, counts conducted at Cidra fluctuated from 52–116 individuals (Wiley 1985), and the population was thought to be <200 individuals mainly restricted to eastcentral Puerto Rico

(Pérez-Rivera 1977, 1981). *Ad hoc* estimates suggested that a population increase occurred between the 1970s and 1990s. For example, Lowe et al. (1990) reported a population of about 250 individuals, del Hoyo et al. (1997) reported about 300 individuals, Birdlife International (2000) reported about 700 individuals, and Oberle (2000) reported about 2000 individuals.

Reliable population parameter estimates are needed to establish recovery goals (Tear et al. 1995) and to assess population viability under adverse deterministic and stochastic processes, such as habitat loss and catastrophic weather (Lande 1993, Sæther et al. 1998). Standard sample surveys were conducted in Puerto Rico during 1986–1992 and 1997–2001 to estimate density, population size, and rate of change over time (Rivera-Milán 1992, 1993, 1995a; Martínez et al. 2001). Based on these parameter estimates, we assessed the population status of Plain Pigeons and make recommendations to continue monitoring trends as part of recovery efforts (U.S. Fish and Wildlife Service 1982, Puerto Rico Dept. of Natural and Environmental Resources 2000).

[1] Dept. of Natural and Environmental Resources, Div. of Terrestrial Resources, Stop 3, Puerta de Tierra, San Juan, PR 00906, USA.

[2] Current address: U.S. Fish and Wildlife Service, Div. of International Conservation, 4401 North Fairfax, Suite 730-ARLSQ, Arlington, VA 22203, USA.

[3] Corresponding author; e-mail: frank_rivera@fws.gov

METHODS

Study area.—Puerto Rico, the smallest (880,190 ha) and easternmost (18° 15′ N, 66° 30′ W) island of the Greater Antilles, lies within the subtropical region, and has six life

zones (Ewel and Whitmore 1973). Its forest cover increased from about 6% during the 1940s (Koenig 1953, Birdsey and Weaver 1982) to about 42% during 1991–1992 (Helmer et al. 2002). About 5% of the island area is protected, but rapid and widespread development is causing the loss and fragmentation of second growth forests (Birdsey and Weaver 1982, 1987; Ramos-González 2001; Helmer et al. 2002).

To collect survey data, we stratified the island according to the area of its three major life zones (dry zone = 121,640 ha, moist zone = 532,610 ha, and wet zone = 212,480 ha; Ewel and Whitmore 1973). Most of the forests in these life zones are characterized by second growth vegetation at different stages of succession (Birdsey and Weaver 1982). For example, early succession second growth forests in the moist zone are characterized by species such as trumpet tree (*Cecropia schreberiana*), American muskwood (*Guarea guidonea*), African tuliptree (*Spathodea campanulata*), and guaba (*Inga vera*).

Point transect surveys.—During each year of the study we conducted point transect surveys during peak nesting activity (March through June) on 8-km routes along secondary (paved) and tertiary (unpaved) roads covering all habitats used by columbids in the life zones. Depending upon topographic features (e.g., winding versus straight roads), the routes had 6–11 points (stations), with the first point of each route placed randomly and the others systematically at 800-m or 1,600-m intervals to minimize the chances of counting the same individuals more than once. We marked point centers so they could be found easily at all times. We used range finders to measure distances from point centers to Plain Pigeons detected singly or in flocks (clusters ≥ 2 individuals). Because we recorded distances to all columbids detected from point centers, distances were grouped into categories (0–15, 15–30, 30–45, 45–60, 60–90, 90–120, 120–180, 180–240, 240–340, 340–440, and >440 m) to secure data quality (Buckland et al. 1993).

We estimated density using the formula:

$$\hat{D} = n\hat{h}(0)\bar{s}/2\pi k,$$

where $\hat{D}$ = the number of individuals/ha; n = the number of individuals counted singly or in clusters; $\hat{h}(0)$ = the slope of the probability density function of detection distances, estimated at zero distance; $\bar{s}$ = mean cluster size; and k = the number of points sampled. At each point, two observers counted for 6 min all the Plain Pigeons seen or heard. We recorded distances to individuals flying overhead only if they were seen landing and their locations could be fixed before they started moving again. We recorded the distance from the center of a point to the center of a cluster of individuals or single individual up to 440 m. Detections beyond 440 m were recorded but not used for density estimation. Because columbids nest year-round (Wiley 1991; Rivera-Milán 1996, 2001; Rivera-Milán et al. 2003) and share a typical pattern of nest attendance (with males on the nest from midmorning to midafternoon or early evening, and females on the nest from late afternoon until midmorning of the next day; Blockstein and Westmoreland 1993), we conducted the surveys from 06:00–10:30 AST to include breeding and nonbreeding individuals of both sexes.

We used program DISTANCE (Thomas et al. 2001) to analyze the point transect survey data. We evaluated the fit of detection models (uniform, half-normal, and hazard-rate key functions with cosine, simple polynomial, and Hermite polynomial parameter adjustments) to data with χ^2 goodness-of-fit tests. Model selection was based on Akaike's Information Criteria (AIC or AIC_c; Burnham and Anderson 1998). Generally, data beyond 180 m were truncated to remove outliers and improve model fitting. If the regression of natural logarithm of cluster size ($\ln[s]$) and detection distance (r) was significant at $\alpha = 0.15$, we used the size-bias regression method to estimate mean cluster size. Encounter rate variance was estimated empirically. Based on data collected in eastcentral Puerto Rico from 1997–2001 ($k = 250$) and throughout the island from 1998–2001 ($k = 765–1,065$), we calculated the number of points (μ) needed to obtain a coefficient of variation (CV) of 20% for estimated density (Buckland et al. 1993: 304–307).

We used a one-tailed z-test (Thompson et al. 1998) to test the hypothesis that log-transformed estimates of density and population size of Plain Pigeons in eastcentral Puerto
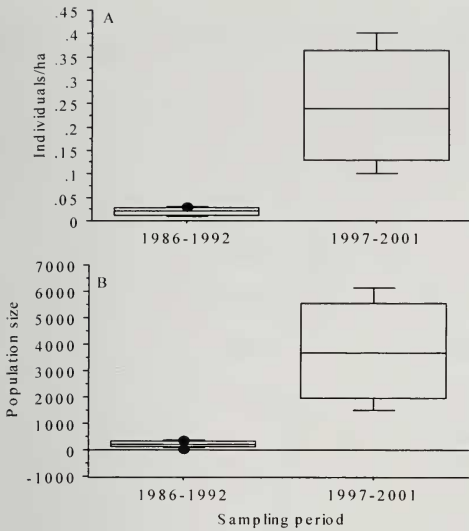
FIG. 1. Box plots of (A) density ($\hat{D}$ = the number of individuals/ha) and (B) population size ($\hat{N}$ = the number of individuals in the area of the surveys) estimates based on point transect survey data collected for Plain Pigeons in eastcentral Puerto Rico from March through June, 1986–1992 (k = 187) and 1997–2001 (k = 250). Percentile ranks (10th, 25th, 50th, 75th, and 90th) are shown, with the top and bottom of each box plot representing the 50th percentile, the line in the middle representing the median, the line extending above representing the 90th percentile and the line extending below representing the 10th percentile, and the circles extending from the lines representing values below the 10th percentile and above the 90th percentile.
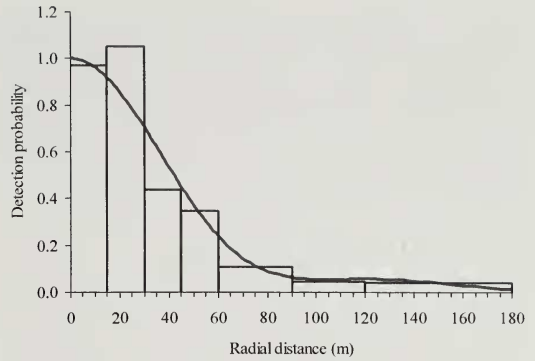

FIG. 2. Distance (r) and detection probability ($g[r]$) of Plain Pigeons based on point transect survey data collected on Puerto Rico during April through June, 2001 (n = 64 and k = 1,065). The half-normal key function + 2-term cosine parameter adjustments provided the most parsimonious fit to the data.

Rico were lower during 1986–1992 (k = 187) than during 1997–2001 (k = 250). To test for positive trends ($\hat{\beta}_1 > 1$) in log-transformed estimates, we used simple linear regression (Nur et al. 1999). Residual plots and residual statistics indicated that the assumptions of regression were met [e.g., ln(population size): Durbin-Watson d = 1.6, $P > 0.05$; serial autocorrelation = 0.2, Box Ljung Q = 0.7, P = 0.40].

RESULTS

Plain Pigeon density estimates ranged from 0.01–0.03 individuals/ha ($\bar{x}$ = 0.02 ± 0.003 SE) and population size estimates in the area of the surveys ($k\pi r^2$ = 11,374 ha) ranged from 60–377 individuals ($\bar{x}$ = 218 ± 42 SE) in eastcentral Puerto Rico during 1986–1992. Density estimates ranged from 0.10–0.40 individuals/ha ($\bar{x}$ = 0.25 ± 0.06 SE) and pop-

ulation size estimates in the area of the surveys ($k\pi r^2$ = 15,205 ha) ranged from 1,497–6,106 individuals ($\bar{x}$ = 3,746 ± 892 SE) during 1997–2001. Estimated density (z = −2.5, P = 0.007) and population size (z = −2.8, P = 0.002) were lower during 1986–1992 than during 1997–2001, respectively (Fig. 1). Rate of change was positive and significant (density: $\hat{\beta}_1$ = 0.29 ± 0.07 SE, t_{12} = 3.9, P = 0.001; population size: $\hat{\beta}_1$ = 0.33 ± 0.09 SE, t_{12} = 3.7, P = 0.002).

Plain Pigeons rarely were detected outside 24 routes (k = 187–250) in eastcentral Puerto Rico. In general, detection probability remained high in the first five distance categories (effective detection distance: $\bar{x}$ = 88 m ± 5 SE), cluster size ($\bar{x}$ = 1.8 ± 0.1 SE) was not related to detection distance, and the half-normal key function with cosine parameter adjustments fitted the data. For example, 64 detections were made in 1,065 points sampled from April through June, 2001, which resulted in a mean effective detection distance of 59 m ± 5 SE, a mean cluster size of 1.03 ± 0.02 SE (regression of ln[s] against r: B_1 = 0.0003 ± 0.0003 SE, t_{62} = 0.9, P = 0.83), and a half-normal key function with cosine parameter adjustments (m = 2) best fitting the data (AIC$_c$ = 245.7; χ^2_4 = 2.3, P = 0.67; Fig. 2).

During 1998–2001 (k = 765–1,065), the coefficient of variation of density estimates ranged from 25–50% ($\bar{x}$ = 35% ± 0.5 SE) and the dispersion parameter estimate ($\hat{b}$) ranged

from 1.9–10.7 ($\bar{x}$ = 6.9 ± 1.8 SE). Because the spatial distribution of Plain Pigeons was clumped ($\hat{b} > 1$), we needed to sample at least 1,195 points throughout the island, with at least 526 points in eastcentral Puerto Rico, to obtain a desired coefficient of variation of 20% for estimated density.

DISCUSSION

In Puerto Rico, Plain Pigeons are multiple-brooded habitat generalists that feed on the fruits of a wide variety of plant species, mainly in mesic second growth forests (Pérez-Rivera 1978). Because density and food abundance are positively related (Rivera-Milán 1992, 1996, 2001; Bancroft et al. 2000; Rivera-Milán et al. 2003), we suggest that the recovery of second growth forests, particularly during the 1970s and 1990s, increased the quantity and quality of foraging and nesting habitats, which in turn elicited a positive population response in eastcentral Puerto Rico between 1986–1992 and 1997–2001. Forest area has increased since the 1940s because marginally productive pasture and cropland were abandoned as Puerto Rico gradually became industrialized (Koenig 1953, Birdsey and Weaver 1982, Helmer et al. 2002).

With a mean density of 0.25 individuals/ha and a mean population size in the area of the surveys of 3,746 individuals during 1997–2001, we believe that the status of the Plain Pigeon is not as precarious as it was during 1986–1992, when mean density was 0.02 individuals/ha and mean population size in the area of the surveys was only 218 individuals. Our optimism is tempered, however, because Plain Pigeons are not widely distributed and unmitigated development is causing major land cover changes (Ramos-González 2001, Helmer et al. 2002), which may be affecting the reproduction of Plain Pigeons through the loss and fragmentation of second growth forests in eastcentral Puerto Rico (Wiley 1985, Pérez-Rivera 1990, Rivera-Milán et al. 2003). Habitat changes may interact with catastrophic weather, food availability, nest predation, illegal hunting, and poaching of nestlings to reduce persistence, even when the population can be increasing exponentially (Mangel and Tier 1994). Illegal hunting, poaching of nestlings, and other forms of human-induced disturbance still occur (Ruiz-Lebrón et al. 1995)

but not as frequently as during the 1970s (U.S. Fish and Wildlife Service 1982, Wiley 1985).

Hurricanes can affect plant and animal populations through multiple effects (Wiley and Wunderle 1994, Wunderle 1995, Lomascolo and Aide 2001). During 1986–2001, two hurricanes struck Puerto Rico: Hugo (a Category 5 hurricane based on the Saffir-Simpson scale) in September 1989 and Georges (Category 3) in September 1998. Hugo had stronger winds but Georges affected a larger portion of the island (for more information, see http://www.geocities.com/huracanado1/). Estimates of density and population size in November 1998 ($\hat{D}$ = 0.01 ± 0.01 SE and $\hat{N}$ = 310 ± 182 SE) were as low as during March through June, 1986–1992, remained depressed during February through October, 1999 ($\hat{D} \leq 0.10 \pm$ 0.03 SE and $\hat{N} \leq 1,497 \pm 523$ SE), and rebounded to pre-hurricane levels during March through June, 2000–2001 ($\hat{D} \geq 0.12 \pm 0.04$ SE and $\hat{N} \geq 1,772 \pm 644$ SE).

As with other columbids (Rivera-Milán 1995b, Wunderle 1995), Plain Pigeons showed resiliency (Pimm 1991), and through successful reproduction responded rapidly to forest regeneration and increased food availability (Rivera-Milán 1996, 2001; Rivera-Milán et al. 2003). However, a hurricane with Hugo's wind force striking the island as did Georges can be devastating for Plain Pigeons. We hypothesize that extensive deforestation from agriculture (Koenig 1953, Birdsey and Weaver 1982), unregulated hunting pressure (Wiley 1985), and the passing through most of the island of hurricanes San Felipe (Category 5) in 1928 and San Ciprián (Category 3) in 1932, interacted to endanger an already reduced and patchily distributed population.

Reliable population monitoring data are needed to evaluate the effectiveness of management actions (Gibbs et al. 1999) and determine if recovery goals have been reached (Tear et al. 1995). Distance sampling theory provided an adequate framework to survey columbids using roads. In the case of the Plain Pigeon, this framework needs to reflect adjustments resulting from their spatially clumped distribution. This distribution may be the result of social behavior, reproductive adaptations, and habitat use with respect to the spatial and proportional distribution of foraging and nesting habitats. Plain Pigeons can

disperse long distances in search of food (Ruiz-Lebrón et al. 1995), but nesting has not been reported outside eastcentral Puerto Rico (Rivera-Milán 1996, 2001; Rivera-Milán et al. 2003). Because second growth forests have similar vegetation structure and composition in the moist zone, we do not know why they are not more widely distributed.

A spatially clumped distribution means that many points will have no detections whereas a few points will have detections of individuals or clusters of individuals. Depending upon the degree of clumping, sampling several hundred or thousand points may be required to obtain reasonably precise density estimates [$CV(\hat{D}) \leq 20\%$]. Currently, 1,065 points are sampled on Puerto Rico annually. This sampling effort is enough to obtain precise density estimates for abundant and widely distributed columbids, such as Scaly-naped Pigeons (*Columba squamosa*), Zenaida Doves (*Zenaida aurita*), and White-winged Doves (*Z. asiatica*). So, given the cost of conducting wide-ranging surveys, we suggest sampling at least 1,195 points throughout the island, with at least 526 points covering eastcentral Puerto Rico. Surveys should be conducted from March through June to cover the peak of nest density of Plain Pigeons and other columbids (Rivera-Milán 1996, 2001; Rivera-Milán et al. 2003). Surveys conducted from March through June (CV: $\bar{x} = 33\% \pm 2$ SE) were less variable than surveys conducted from July through February (CV: $\bar{x} = 47\% \pm 7$ SE) because of changes in flocking behavior (Rivera-Milán 1992, 1993, 1995a; FFR-M unpubl. data).

Plain Pigeons were detected easily and grouped into distance categories ranging from 0–15 m to 340–440 m. In general, detection probability remained high near point centers and decreased with distance, cluster size was not a function of detection distance, and detectability followed a half-normal process (Buckland et al. 1993). Plain Pigeons were detected near (0–30 m) and far ($\geq$120 m) from roads because they frequently perched at canopy level and moved conspicuously within and between forest fragments. To be conservative, however, we did not estimate population size beyond the surveyed area ($k\pi r^2$) because placement of sampling units on or near roads may not be representative of their abundance in off-road habitats (Buckland et al. 1993, Thompson 2002). Further research is needed to validate sample inferences from on-road to off-road habitats (Keller and Scallan 1999).

Islandwide surveys would be impossible without the use of roads. Secondary and tertiary roads provide access to all habitat types used by columbids, ranging from upper montane wet forests to coastal dry forests. In Puerto Rico, Plain Pigeons behave as edge species (Yahner 1988), nesting, foraging, and roosting in trees at or near roads. Thus, we believe that point transect surveys along roads provided adequate coverage of their habitats and daily activities, and we recommend combining distance sampling with telemetry and geographic information systems to link demographic and spatial data. These data should be used to establish specific population and habitat recovery goals (Tear et al. 1995) for the downlisting and delisting of Plain Pigeons in Puerto Rico.

ACKNOWLEDGMENTS

LITERATURE CITED

BANCROFT, G. T., R. BOWMAN, AND R. J. SAWICKI. 2000. Rainfall, fruiting phenology, and the nesting season of White-crowned Pigeons in the upper Florida Keys. Auk 117:615–626.

BIRDLIFE INTERNATIONAL. 2000. Threatened birds of the world. Lynx Edicions and Birdlife International, Barcelona, Spain, and Cambridge, United Kingdom.

BIRDSEY, R. A. AND P. L. WEAVER. 1982. The forest resources of Puerto Rico. U.S. Forest Service Resource Bulletin SO-85, New Orleans, Louisiana.

BIRDSEY, R. A. AND P. L. WEAVER. 1987. Forest area trends in Puerto Rico. U.S. Forest Service Resource Note SO-331, New Orleans, Louisiana.

BLOCKSTEIN, D. AND D. WESTMORELAND. 1993. Reproductive strategy. Pp. 105–116 in Ecology and management of the Mourning Dove (T. S. Baskett, M. W. Sayre, R. E. Tomlinson, and R. E. Mirarchi, Eds.). Stackpole Books, Harrisburg, Pennsylvania.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance sampling. Chapman and Hall, New York.

Burnham, K. P. and D. R. Anderson. 1998. Model selection and inference. Springer-Verlag, New York.

Danforth, S. T. 1931. Puerto Rican ornithological records. J. Agric. Univ. of Puerto Rico 15:33–106.

Del Hoyo, J., A. Elliot, and J. Sargatal. 1997. Handbook of the birds of the world, vol. 4. sandgrouse to cuckoos. Lynx Edicions, Barcelona, Spain.

Ewel, J. J. and J. L. Whitmore. 1973. The ecological life zones of Puerto Rico and the U.S. Virgin Islands. U.S. Forest Service Research Paper ITF-18, Río Piedras, Puerto Rico.

Gibbs, J. P., H. L. Snell, and C. E. Causton. 1999. Effective monitoring for adaptive wildlife management: lessons from the Galapagos Islands. J. Wildl. Manage. 63:1055–1065.

Gundlach, J. 1878. Apuntes para la fauna puertorriqueña. Anales de la sociedad Española de Historia Natural, Madrid, Spain.

Helmer, E. H., O. Ramos, T. Del M. López, M. Quiñones, and W. Diaz. 2002. Mapping the forest type and land cover of Puerto Rico, a component of the Caribbean biodiversity hotspot. Caribb. J. Science 38:165–283.

Keller, C. M. E. and J. T. Scallan. 1999. Potential roadside biases due to habitat changes along breeding bird survey routes. Condor 101:50–57.

Koenig, N. 1953. A comprehensive agricultural program for Puerto Rico. U.S. Dept. of Agriculture, Washington, D.C.

Lande, R. 1993. Risks of population extinction from demographic and environmental stochasticity, and random catastrophes. Am. Nat. 142:911–927.

Leopold, N. F. 1963. A checklist of the birds of Puerto Rico and the U.S. Virgin Islands. Bull. No. 168, Agricultural Experimental Station, Río Piedras, Puerto Rico.

Lomascolo, T. and T. M. Aide. 2001. Seed and seedling bank dynamics in secondary forests following Hurricane Georges in Puerto Rico. Caribb. J. Sci. 37:259–270.

Lowe, D. W., J. R. Matthews, and C. J. Moseley. 1990. The official World Wildlife Fund guide to endangered species of North America, vol. 2. Beachman Publishers, Washington, D.C.

Mangel, M. and C. Tier. 1994. Four facts every conservation biologist should know about persistence. Ecol. 75:607–614.

Martínez, A., D. Guzmán, A. Matos, A. Ortiz, and C. Vázquez. 2001. Annual performance report, project W-16. Puerto Rico Dept. of Natural and Environmental Resources, San Juan.

Miyamoto, M. M., M. W. Allard, and J. A. Moreno. 1994. Conservation genetics of the Plain Pigeon (*Columba inornata*) in Puerto Rico. Auk 111:910–916.

Nur, N., S. L. Jones, and G. R. Geupel. 1999. A statistical guide to data analysis of avian monitoring programs. USFWS Biological Technical Publication BTP-R6001-1999, Washington, D.C.

Oberle, M. W. 2000. Puerto Rico's birds in photographs. Editorial Humanitas, San Juan, Puerto Rico.

Pérez-Rivera, R. A. 1977. El status de la paloma sabanera (*Columba inornata wetmorei*) en Puerto Rico. Science-Ciencia 5:39–40.

Pérez-Rivera, R. A. 1978. Preliminary work on the feeding habits, nesting habitat and reproductive activities of the Plain Pigeon (*Columba inornata wetmorei*) and the Red-necked Pigeon (*Columba squamosa*), sympatric species: an analysis of their interaction. Science-Ciencia 5:89–97.

Pérez-Rivera, R. A. 1981. Notas adicionales sobre la distribución de la paloma sabanera (*Columba inornata wetmorei*) en Puerto Rico. Science-Ciencia 8:19–24.

Pérez-Rivera, R. A. 1990. Sobre la situación de la paloma ceniza o sabanera (*Columba inornata*) en las Antillas Mayores. Science-Ciencia 17:21–25.

Pimm, S. L. 1991. Balance of nature? Univ. of Chicago Press, Chicago, Illinois.

Puerto Rico Dept. of Natural and Environmental Resources. 2000. Delimitación del hábitat de la paloma sabanera (*Columba inornata wetmorei*) dentro de los municipios de Cidra, Comerío, y Caguas, Puerto Rico. Puerto Rico Dept. of Natural and Environmental Resources, San Juan.

Ramos-González, O. M. 2001. Assessing vegetation and land cover changes in northeastern Puerto Rico: 1978–1995. Caribb. J. Sci. 37:95–106.

Rivera-Milán, F. F. 1992. Distribution and relative abundance patterns of columbids in Puerto Rico. Condor 92:224–238.

Rivera-Milán, F. F. 1993. Standardization of roadside counts of columbids in Puerto Rico and on Vieques Island. U.S. National Biological Survey Resource Publ. 197, Washington, D.C.

Rivera-Milán, F. F. 1995a. Spatial and temporal variation in the detectability and density of columbids in Puerto Rico and on Vieques Island. Neotrop. Ornithol. 6:1–17.

Rivera-Milán, F. F. 1995b. Detectability and population density of Scaly-naped Pigeons before and after Hurricane Hugo in Puerto Rico and Vieques Island. Wilson Bull. 107:727–733.

Rivera-Milán, F. F. 1996. Nest density and success of columbids in Puerto Rico. Condor 98:100–113.

Rivera-Milán, F. F. 1999. Population dynamics of Zenaida Doves in Cidra, Puerto Rico. J. Wildl. Manage. 63:232–244.

Rivera-Milán, F. F. 2001. Transect surveys of columbid nests on Puerto Rico, Vieques, and Culebra Islands. Condor 103:332–342.

Rivera-Milán, F. F., C. R. Ruiz, J. A. Cruz, and J. A. Sustache. 2003. Reproduction of Plain Pigeons (*Columba inornata wetmorei*) in east-central Puerto Rico. Auk 120:466–480.

Ruiz-Lebrón, C. A., D. J. Galán-Kercado, and R. A.

PÉREZ-RIVERA. 1995. Segunda liberación experimental de palomas sabaneras en Cidra, Puerto Rico. El Pitirre 8:5–7.

SÆTHER, B. E., S. ENGEN, A. ISLAM, R. MCCLEERY, AND C. PERRINS. 1998. Environmental stochasticity and extinction risk in a population of a small songbird, the Great Tit. Am. Nat. 151:441–450.

STRONG, A. M. AND M. D. JOHNSON. 2001. Exploitation of a seasonal resource by nonbreeding Plain and White-crowned pigeons: implications for conservation of tropical dry forests. Wilson Bull. 113:73–77.

TEAR, T. H., J. M. SCOTT, P. H. HAYWARD, AND B. GRIFFITH. 1995. Recovery plans and the Endangered Species Act: are criticisms supported by the data. Conserv. Biol. 9:182–195.

THOMAS, L., J. L. LAAKE, J. F. DERRY, S. T. BUCKLAND, D. L. BORCHERS, D. R. ANDERSON, K. P. BURNHAM, S. L. HEDLEY, AND J. H. POLLARD. 2001. Distance 4.0 ver. 1. Research Unit for Wildlife Population Assessment, Univ. of St. Andrews, St. Andrews, United Kingdom.

THOMPSON, W. L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. Auk 119:18–25.

THOMPSON, W. L., G. C. WHITE, AND C. GOWAN. 1998. Monitoring vertebrate populations. Academic Press, San Diego, California.

U.S. FISH AND WILDLIFE SERVICE. 1982. Puerto Rican Plain Pigeon recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.

WETMORE, A. 1916. Birds of Porto Rico. U.S. Dept. of Agriculture Bull. 326., Washington, D.C.

WILEY, J. W. 1985. Bird conservation in the United States Caribbean. Pp. 107–159 *in* Bird conservation, vol. 2 (S. A. Temple, Ed.). Univ. of Wisconsin Press, Madison.

WILEY, J. W. 1991. Ecology and behavior of the Zenaida Dove. Neotrop. Ornithol. 2:49–75.

WILEY, J. W. AND J. M. WUNDERLE, JR. 1994. The effects of hurricanes on birds, with special reference to the Caribbean islands. Bird Conserv. Internat. 4:1–31.

WUNDERLE, J. M., JR. 1995. Responses of bird populations in a Puerto Rican forest to Hurricane Hugo: the first 18 months. Condor 97:879–896.

YAHNER, R. H. 1988. Changes in wildlife communities near edges. Conserv. Biol. 2:33–339.